

High Power Switching and Combining Technique

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The X-band radar will radiate 400-kW of output power by paralleling two 250-kW klystron amplifiers. The klystron outputs will be summed into a single waveguide by properly phasing in a 3-dB short-slot hybrid. To obtain preliminary data on combining the outputs of two klystrons and switching the power between the antenna and water load, tests were conducted using two S-band 20-kW klystrons. These test results also apply at X-band since the hybrid is bilateral and linear.

I. Introduction

The X-band radar, described in Ref. 1, will radiate 400-kW of output power by paralleling two 250-kW klystron amplifiers (see article on *X-Band 250-kW Klystron*, by R. H. Smith, in this issue). The klystron outputs will be summed into a single waveguide by properly phasing in a 3-dB short-slot hybrid.

In addition, there is a requirement for long pulse modulation (i.e., 10 seconds on/10 seconds off). This type modulation, when applied to the beam voltage and/or RF drive on/off switching, drastically reduces the life of the klystron since the thermal time constant of the massive copper collector is approximately one second. One tech-

nique for maintaining the life expectancy of the klystron and providing the on/off modulation capability is to switch the phase of one input to the combiner by 180 deg as illustrated in Fig. 1. This switches the total output power of 400 kW to the water load. The residual power going to the antenna will be a function of the hybrid isolation, relative phase of the two inputs, and the voltage standing wave ratio (VSWR) at the outputs of the hybrid.

To obtain preliminary data on combining the outputs of two klystrons and switching the power between the antenna and water load (Fig. 1), tests were conducted using two S-band 20-kW klystrons. These test results also apply at X-band since the hybrid is bilateral and linear.

II. Summary

The test results indicate that using the combiner as a high power switch will provide at least a 30-dB isolation at the antenna port with very little difficulty. The total output power can be maintained within ± 0.1 dB with a feedback loop on the phase controller. The relative input phase to the hybrid must be controlled within ± 5 deg.

III. Test Procedure

As stated, the tests were to obtain preliminary data on using a short-slot hybrid as a power combiner and a high power switch. The tests were conducted using two S-band 20-kW klystrons (5K70SG) operating into a 90-deg 3-dB short-slot hybrid. The S-band hybrid is similar to the one designed for the X-band radar. For these tests the two output ports of the S-band hybrid were terminated with water loads, one load simulating the antenna. In order to combine the output of each klystron into water load 1 (WL 1), the relative phase at the hybrid inputs must be 90 deg, as shown in Fig. 2. The relative phase was controlled by adjusting the helix voltage on one of the TWT driver amplifiers. The following tests were conducted:

- (1) Determine power variation at (summed port) WL 1 as a function of the relative phase of the two inputs.
- (2) Determine power variation at WL 2 (difference port) as a function of the relative phase of the two inputs.
- (3) Determine amplitude stability of the power in WL 1 as a function of time and without feedback control for phase correlation.

Both klystrons were tuned broadband, saturated at 10 kW, and operated at a frequency of 2115 MHz.

IV. Test Results

The results of the first test are shown in Fig. 3. The radar specification for amplitude variation is ± 0.5 dB. As can be seen from the data, amplitude variation due to phase variation is about ± 0.1 dB at $\pm 10\%$ relative phase change. Figure 4 shows the power level at WL 2 as the relative input phases are changed. The ratio of this power to the power at the sum port WL 1 is the measured isolation of the hybrid. The data show the isolation at the difference port (WL 2) to be between 26 dB and 30 dB for a ± 5 -deg relative change.

One point to consider is that the S-band hybrid used for these tests has 7 dB less isolation than the X-band hybrid when tested (low power) with matched loads.

A three-hour stability test was run monitoring the total power at the summed port (WL 1) with no feedback loop to the phase controller. The power variation at WL 1 was less than 0.1 dB, indicating from Fig. 3 that the relative phase variation was less than ± 10 deg. However, the relative phase stability required to maintain minimum power at the difference port, whether it be the antenna or water load as shown in Fig. 1, requires a maximum relative phase change of ± 5 deg. Therefore, it appears that a closed loop system for the phase controller is required.

Figures 5 and 6 give the performance of the hybrid as a result of changing various parameters in the 5K70SG klystron. These data were obtained by using the standard transmitter drive and output monitoring circuitry in connection with the network analyzer connected to the input and output RF sample ports shown in Fig. 2. Figure 5 gives drive, relative phase shift, and output power as a function of beam voltage for saturated operation. Figure 6 shows power output and relative phase shift as a function of drive level at a fixed beam voltage.

Reference

1. Wiggins, C. P., "X-Band Radar Development," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XII, pp. 19-21. Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1972.

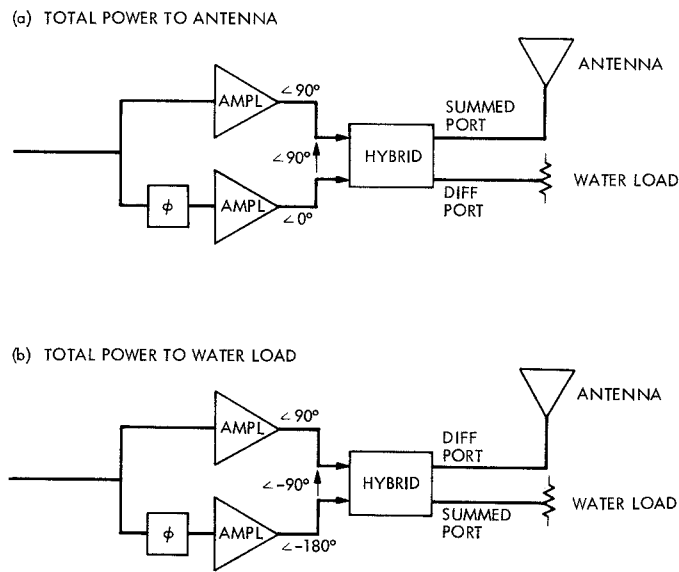


Fig. 1. Illustration of switching output power between antenna and water load

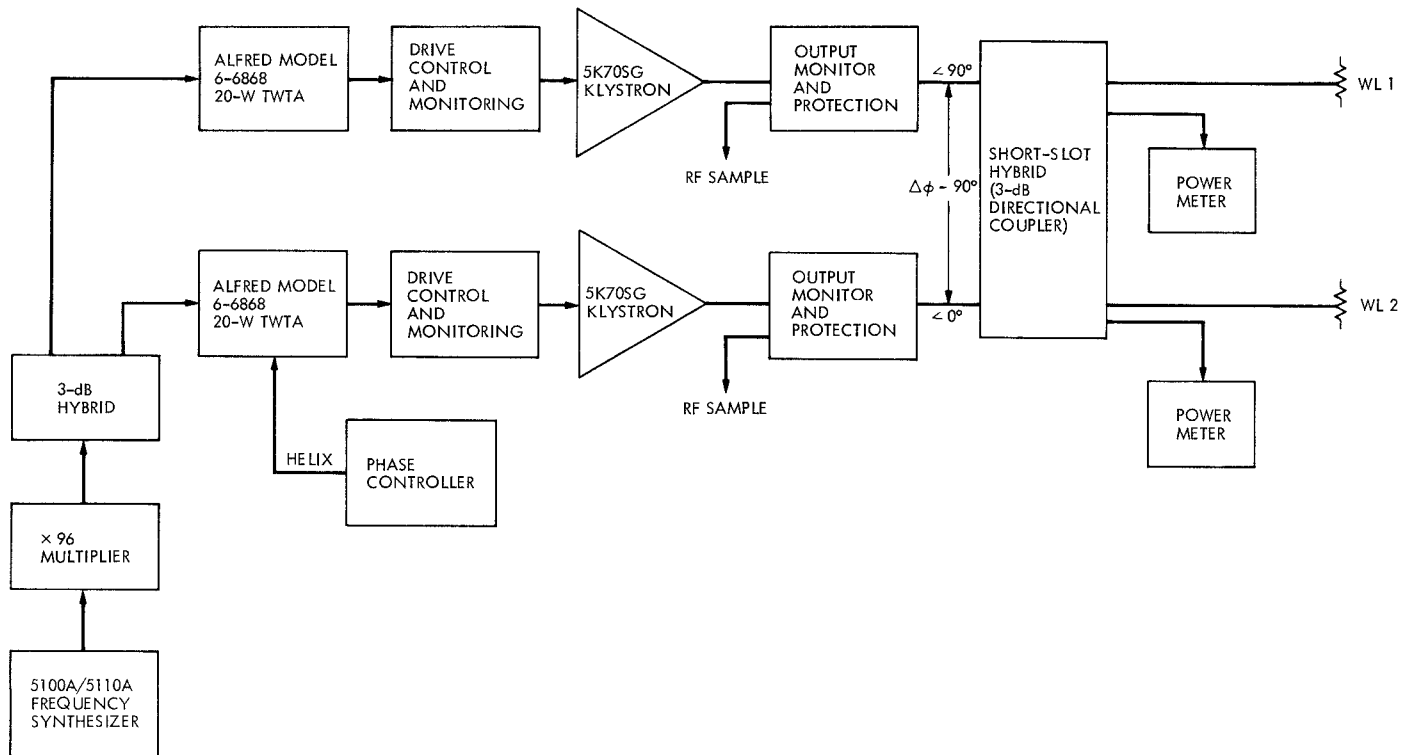


Fig. 2. Phased-transmitter test configuration

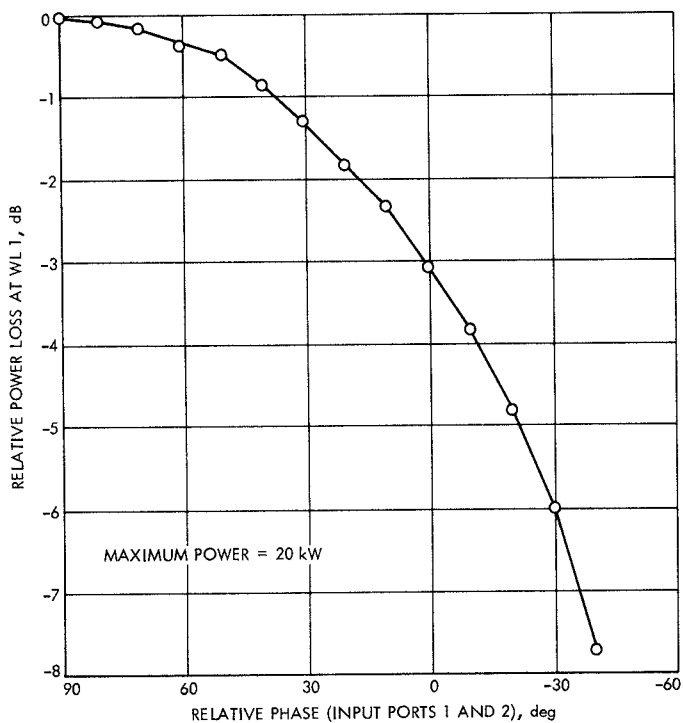


Fig. 3. Results of first test

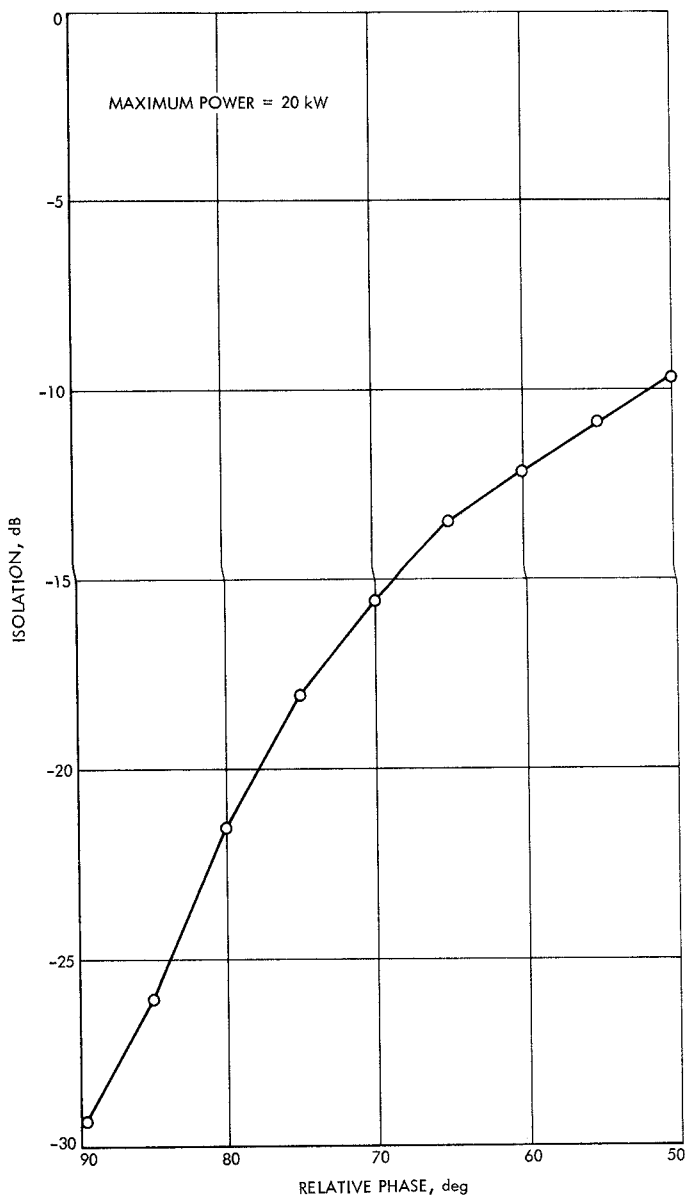


Fig. 4. Power level at WL 2 as relative input phases are changed

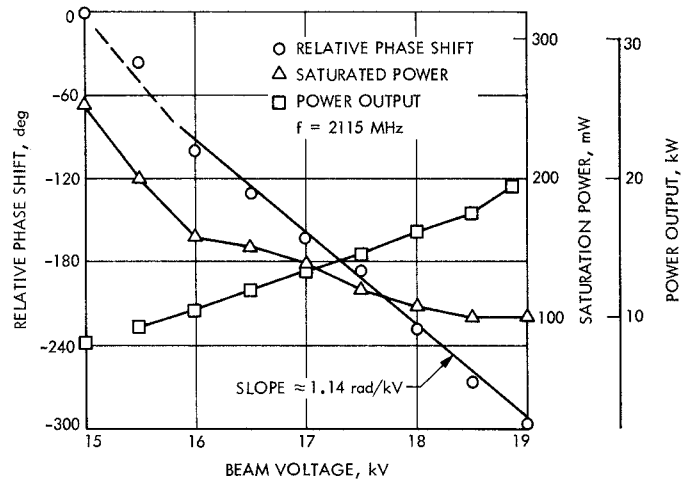


Fig. 5. Performance of 5K70SG klystron for saturated operation

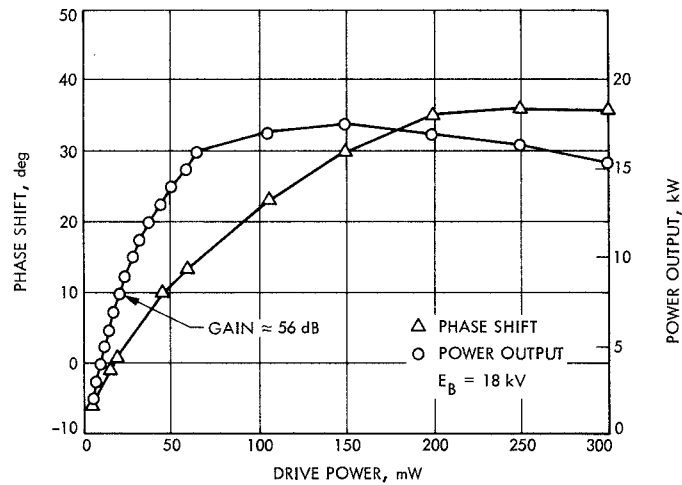


Fig. 6. Performance of 5K70SG klystron at fixed beam voltage